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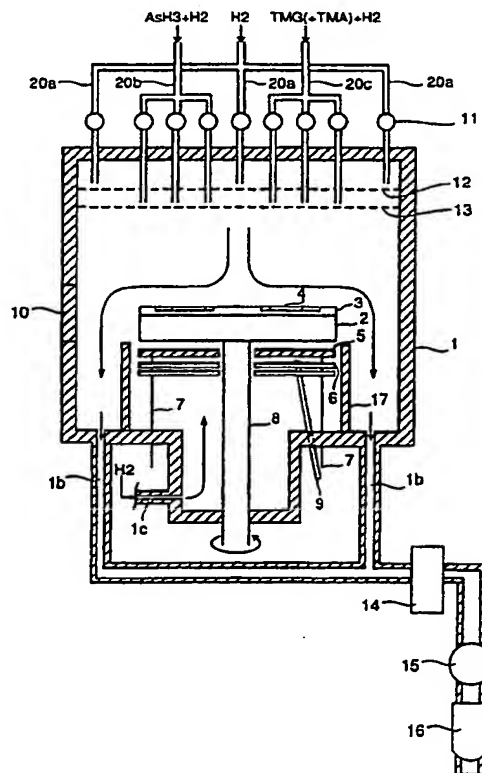
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## (54) Chemical vapour deposition apparatus

(57) A chemical vapor deposition apparatus for crystal growth on a wafer (4) disposed in a reaction chamber (1) in which material gases are supplied from an upper part of the reaction chamber (1) while the material gases are exhausted from a bottom of the reaction chamber (1), the apparatus further includes a susceptor (2) on which the wafer (4) is put, a heater (5) disposed under the susceptor (2) for heating the susceptor (2), and a detachable cylindrical member (17) disposed at the bottom of the reaction chamber (1) so as to cover parts under the susceptor (2) and prevent the material gases from flowing around the parts under the susceptor (1). In this structure, since parts disposed under a susceptor (2) are surrounded by the cylindrical member (17), material gases are not likely to go around the parts. Consequently, the growth temperature is stabilized and the maintenance in the reaction chamber is facilitated. Other embodiments described include an exhaust vent in a side wall (Fig 2); an auxiliary material gas supplying pipe (Fig 4); and a heated mesh disposed under outlets of the material gas supplying pipes (Fig 6).

Fig.1



GB 2 282 825 A

Fig.1

1/13

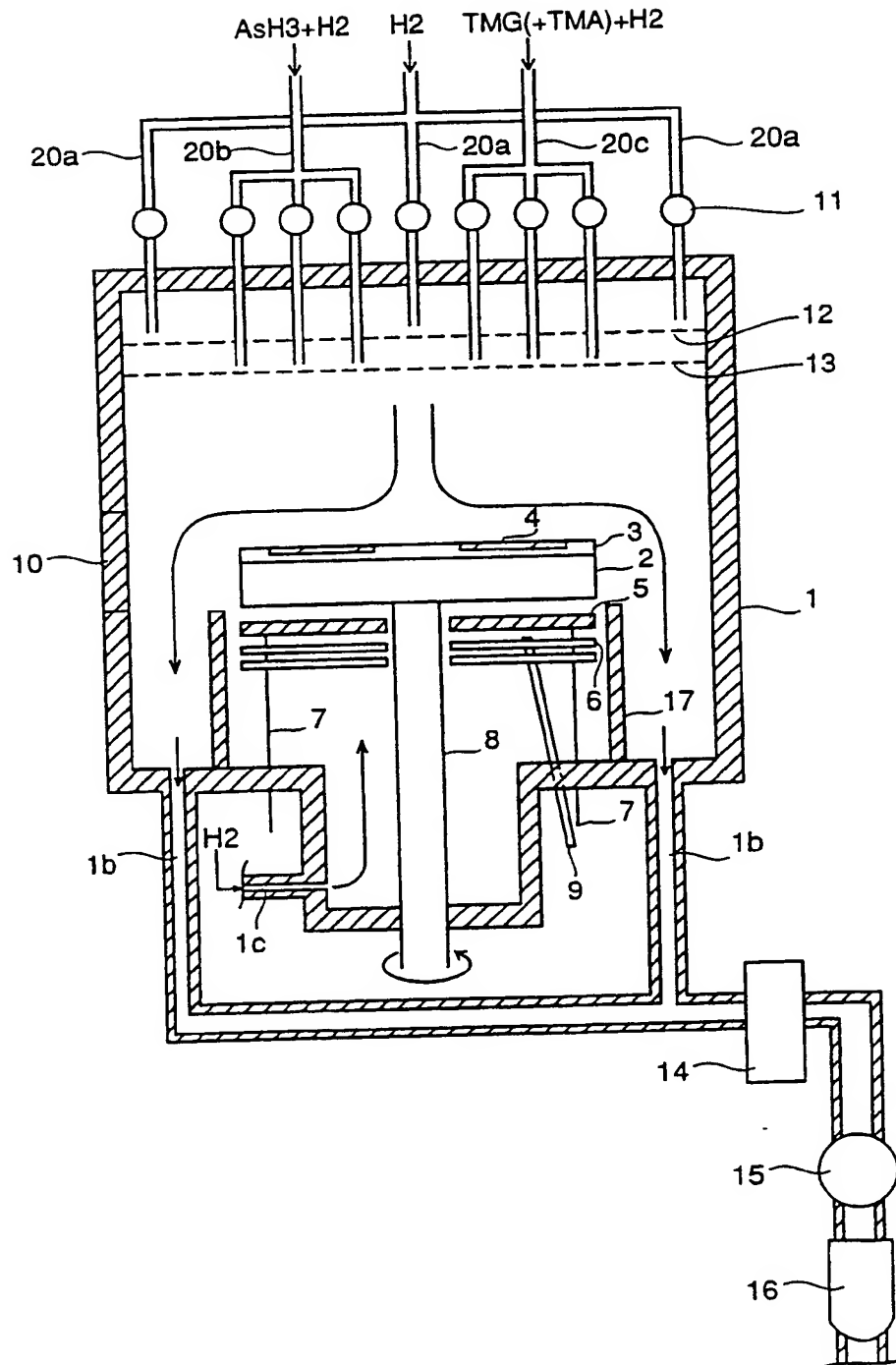
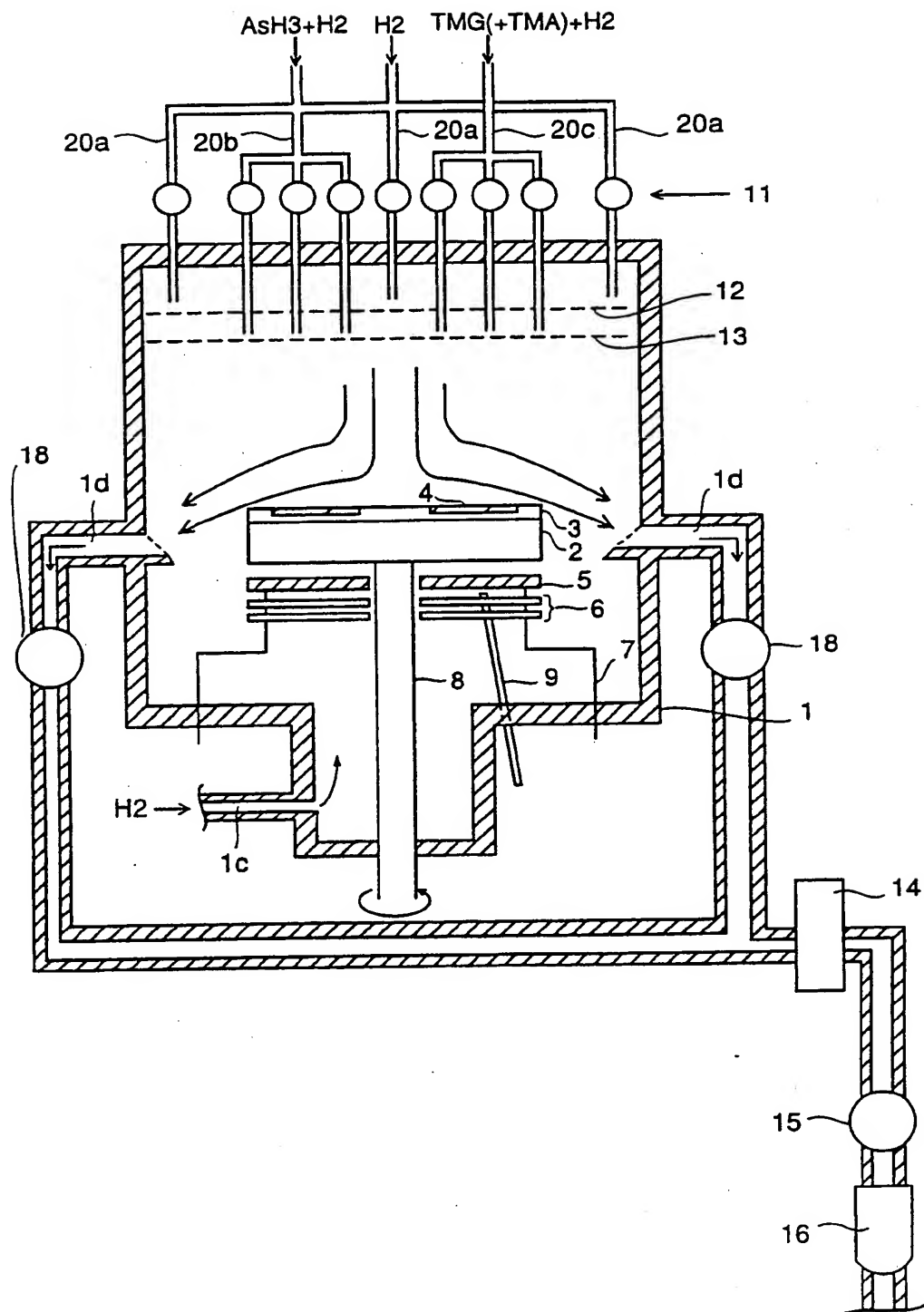
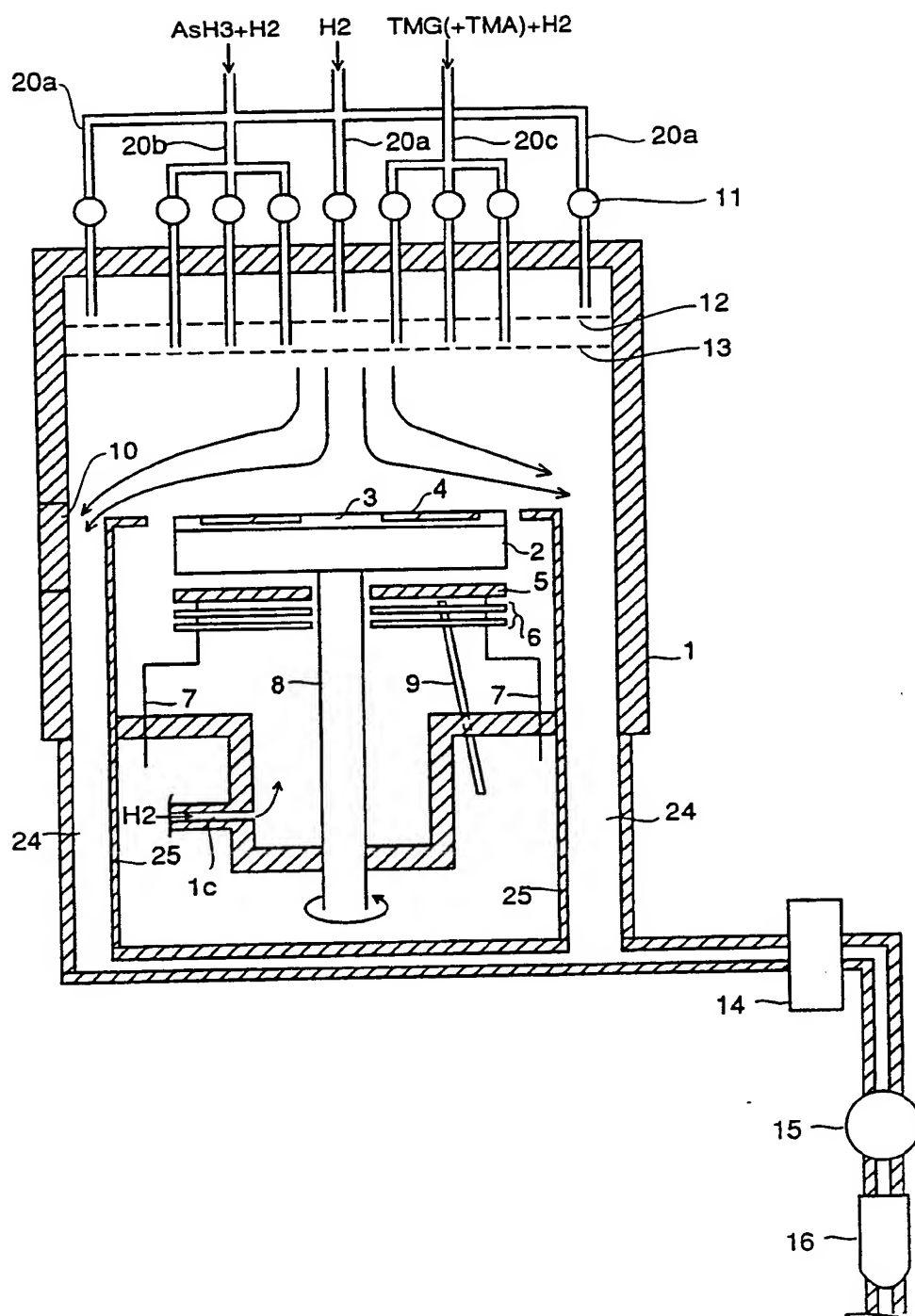


Fig.2

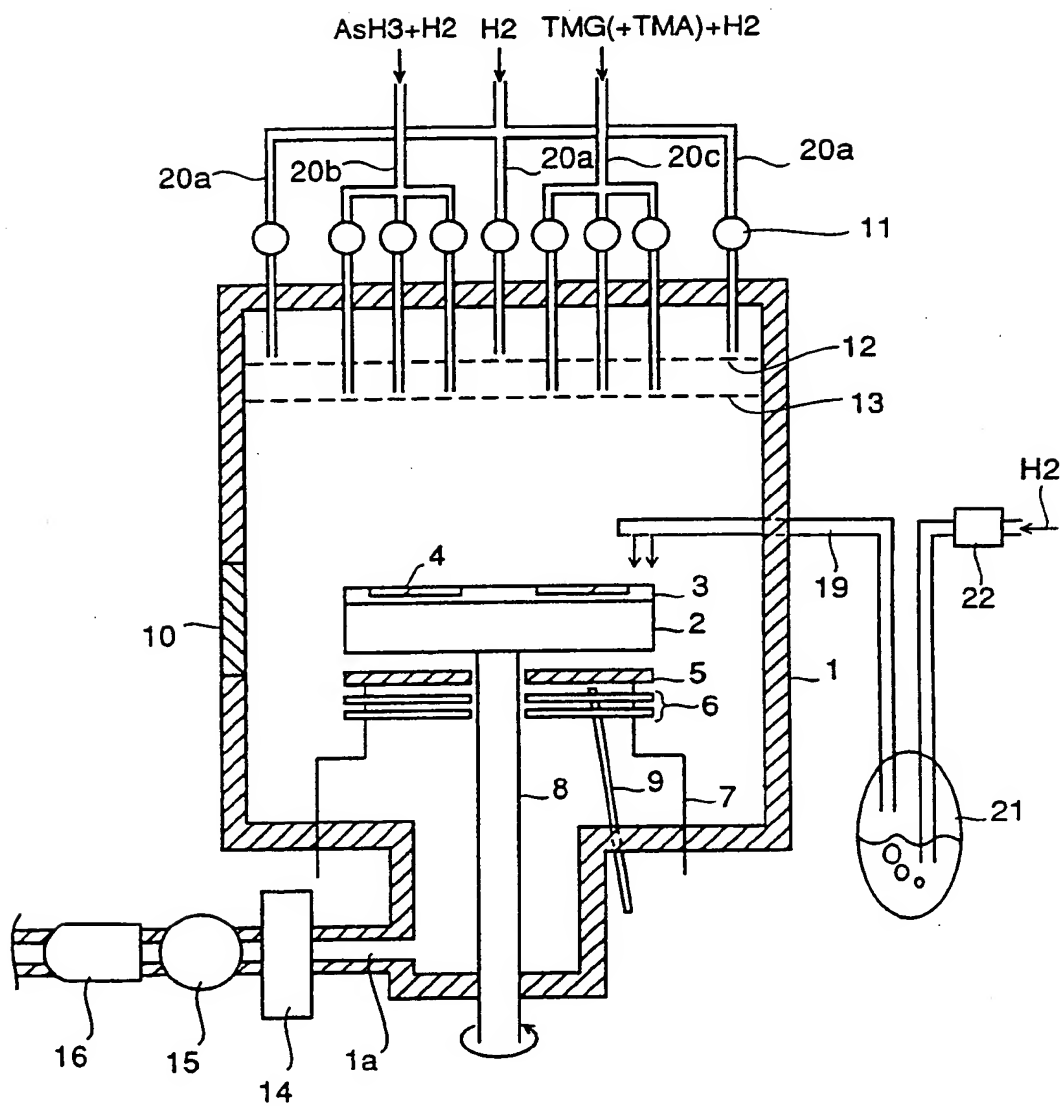
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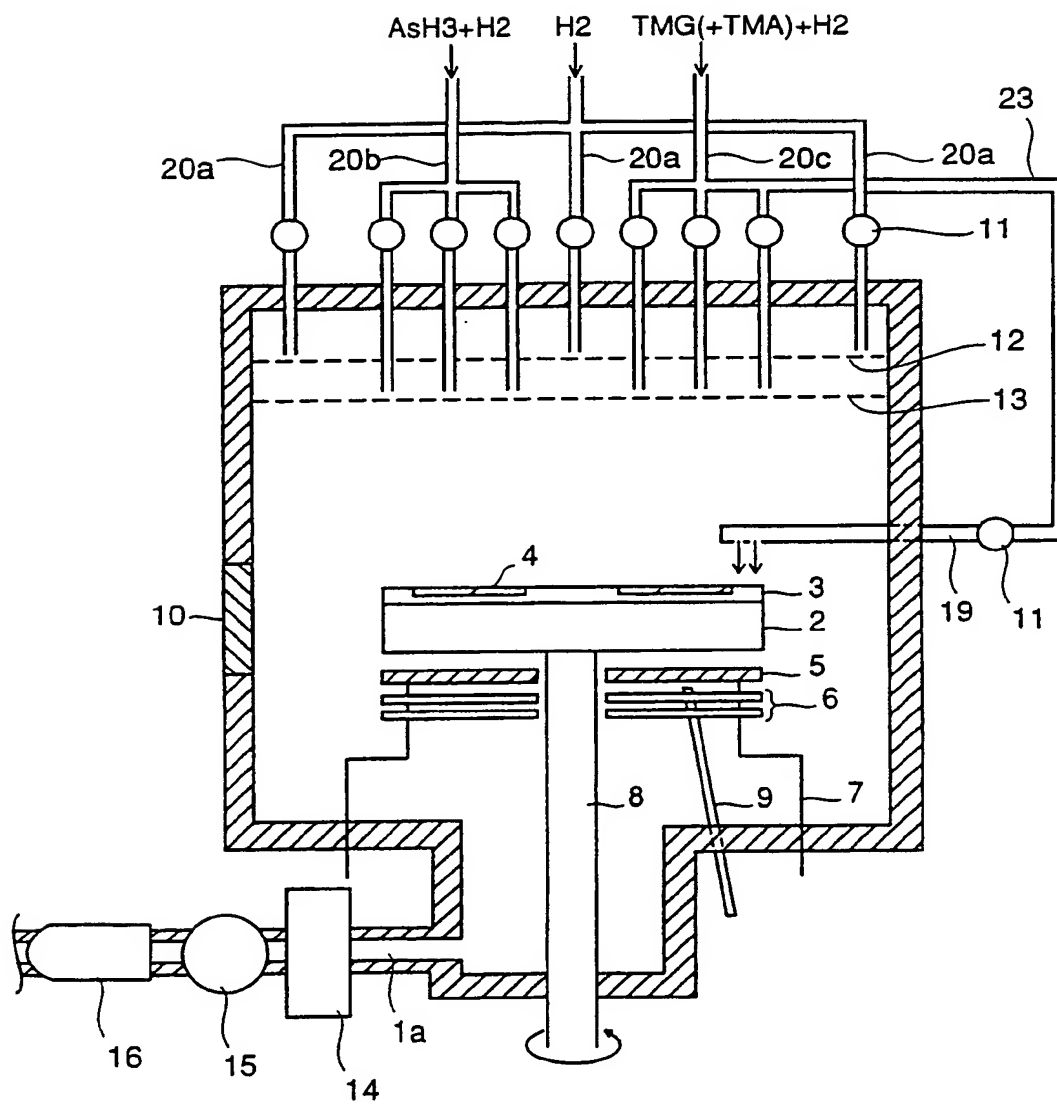
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Fig.4



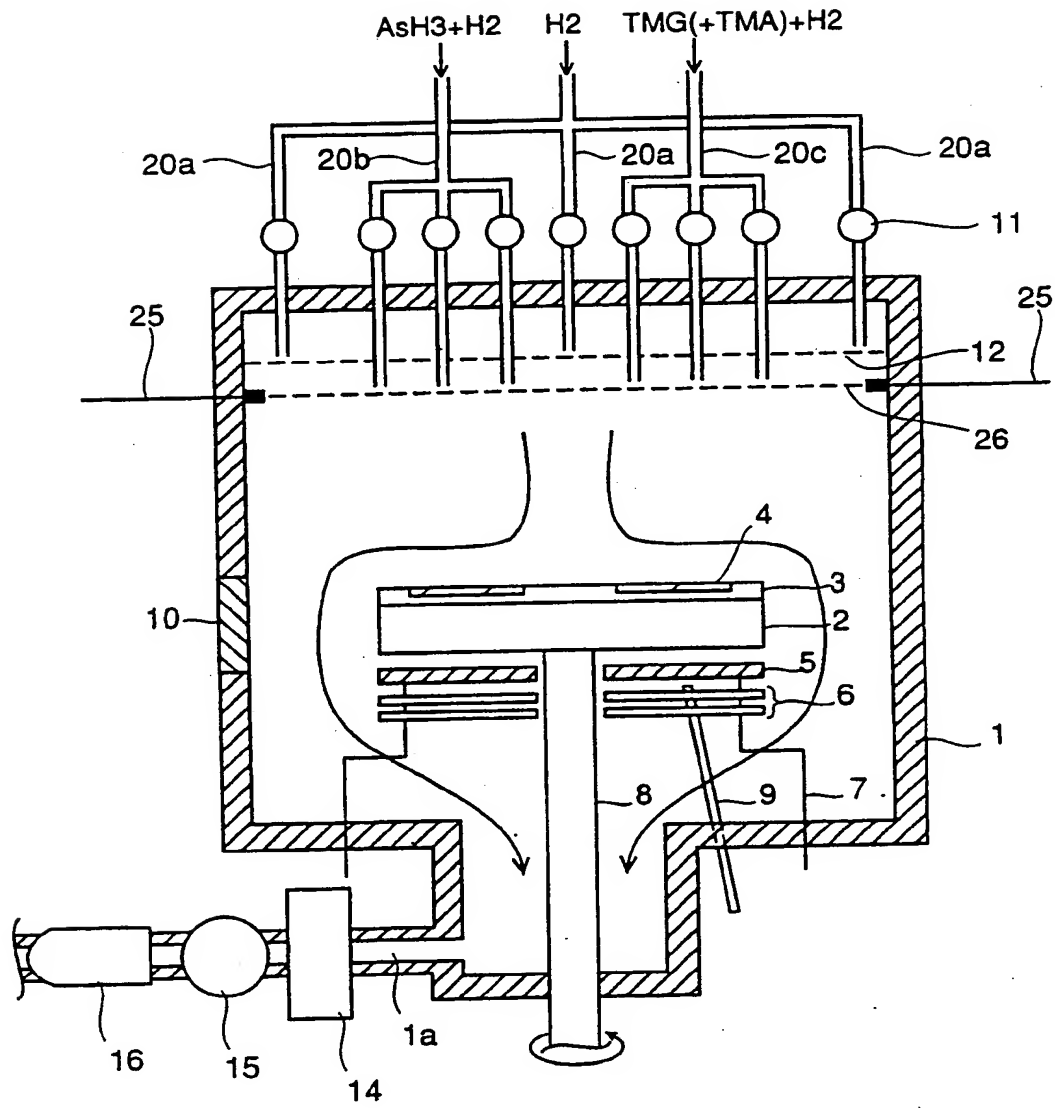
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Fig.5



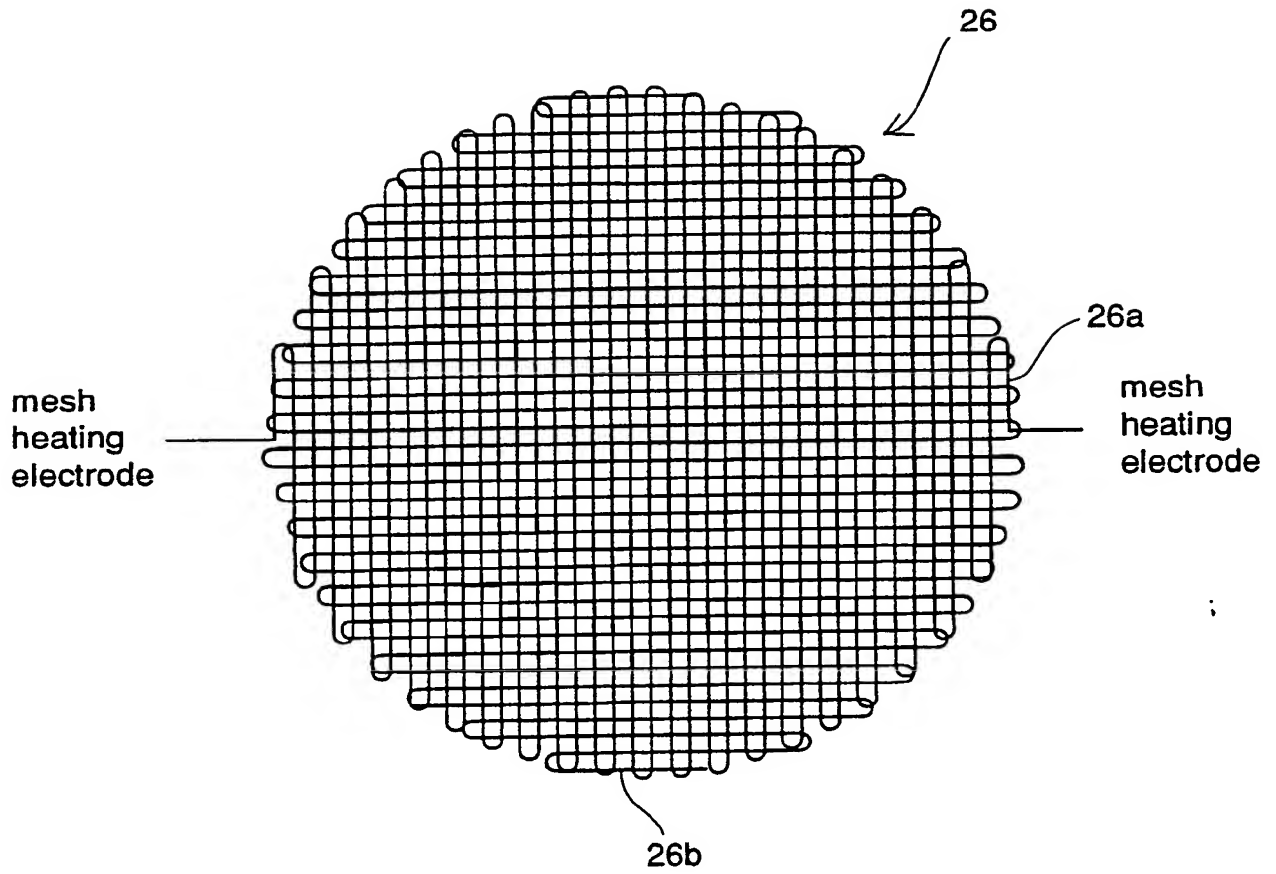
6/13

Fig.6



7/13

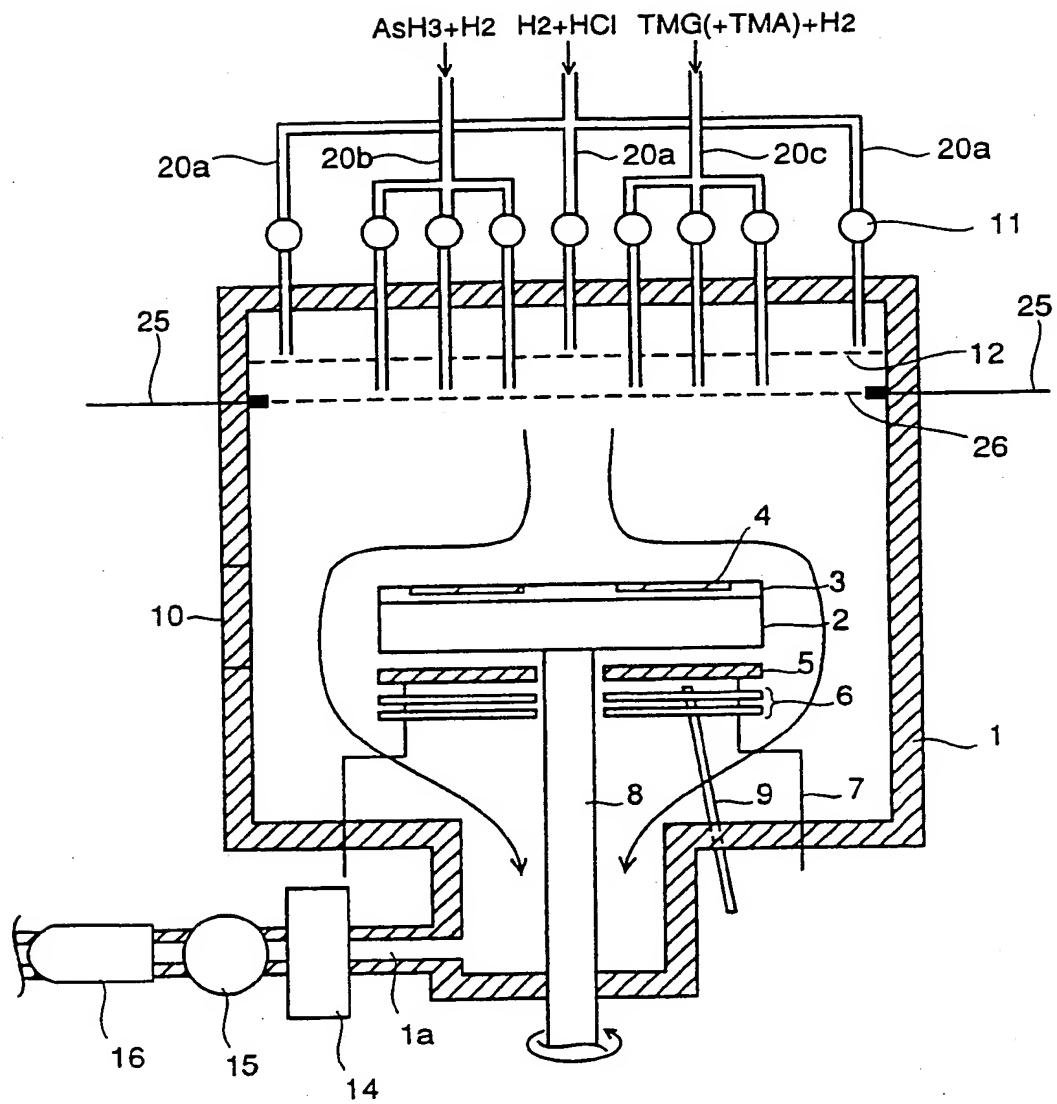
Fig.7





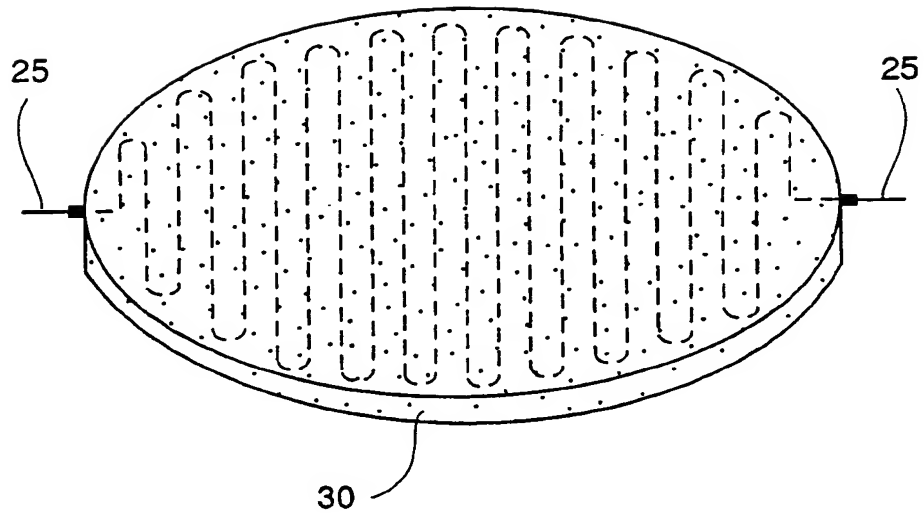
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Fig.8



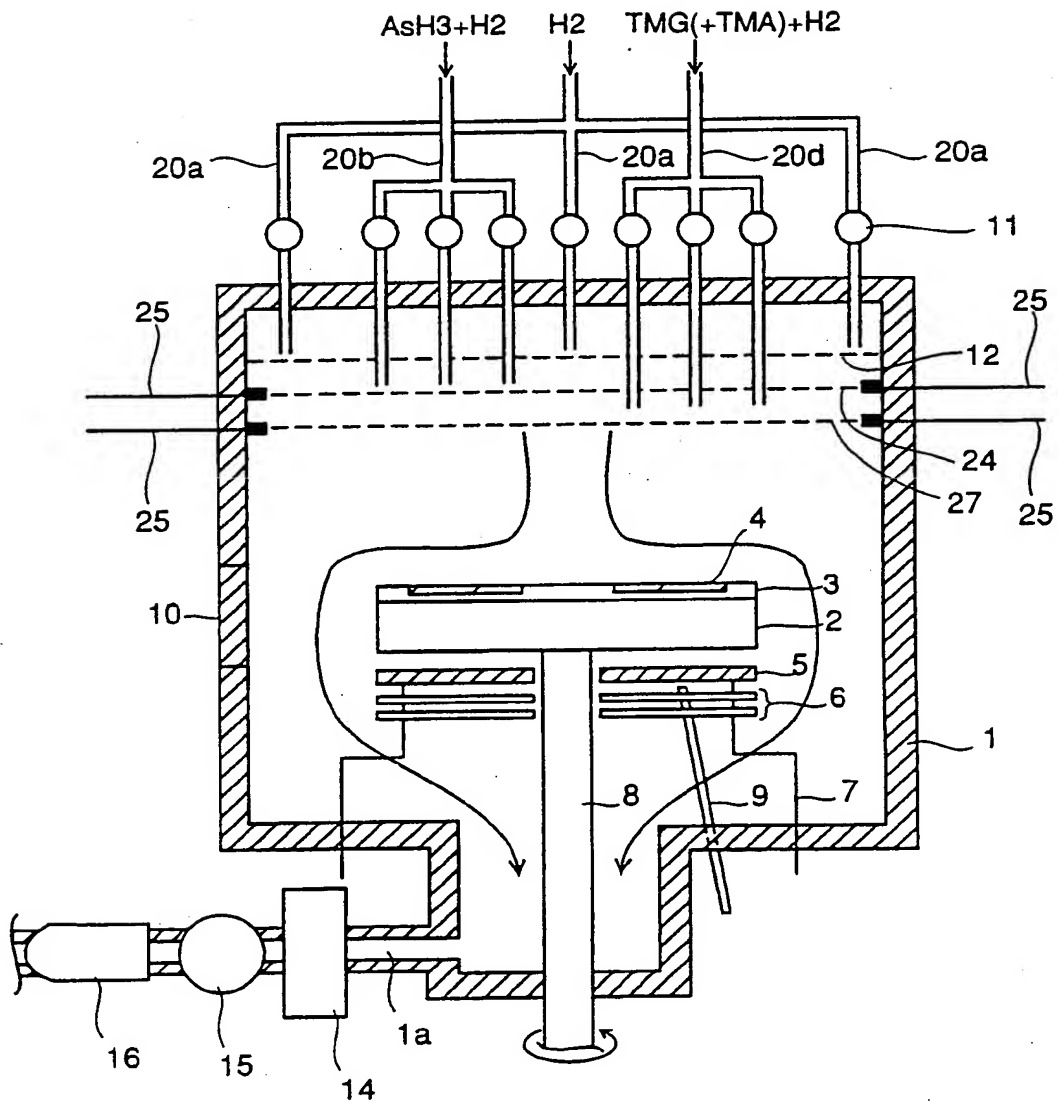
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Fig.9



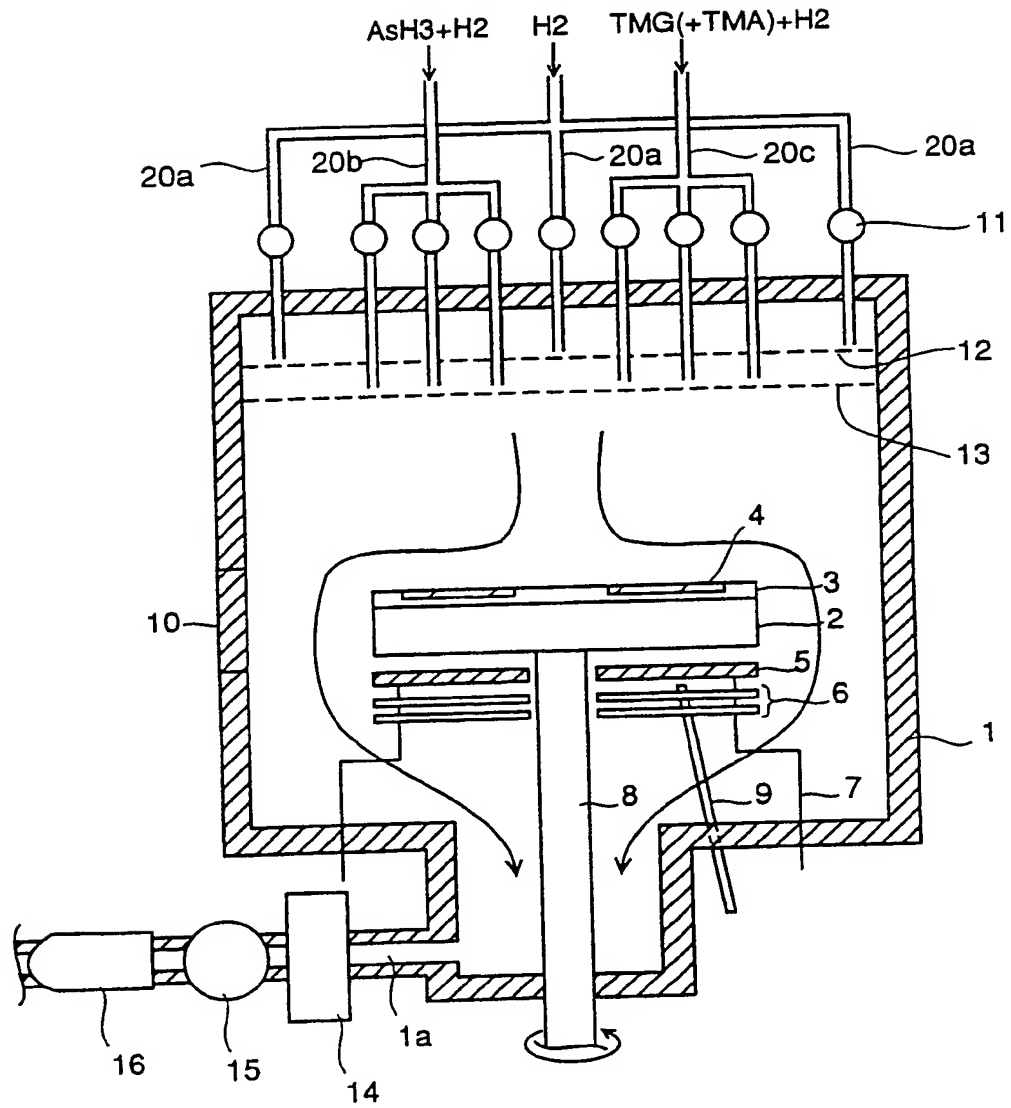
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Fig.10



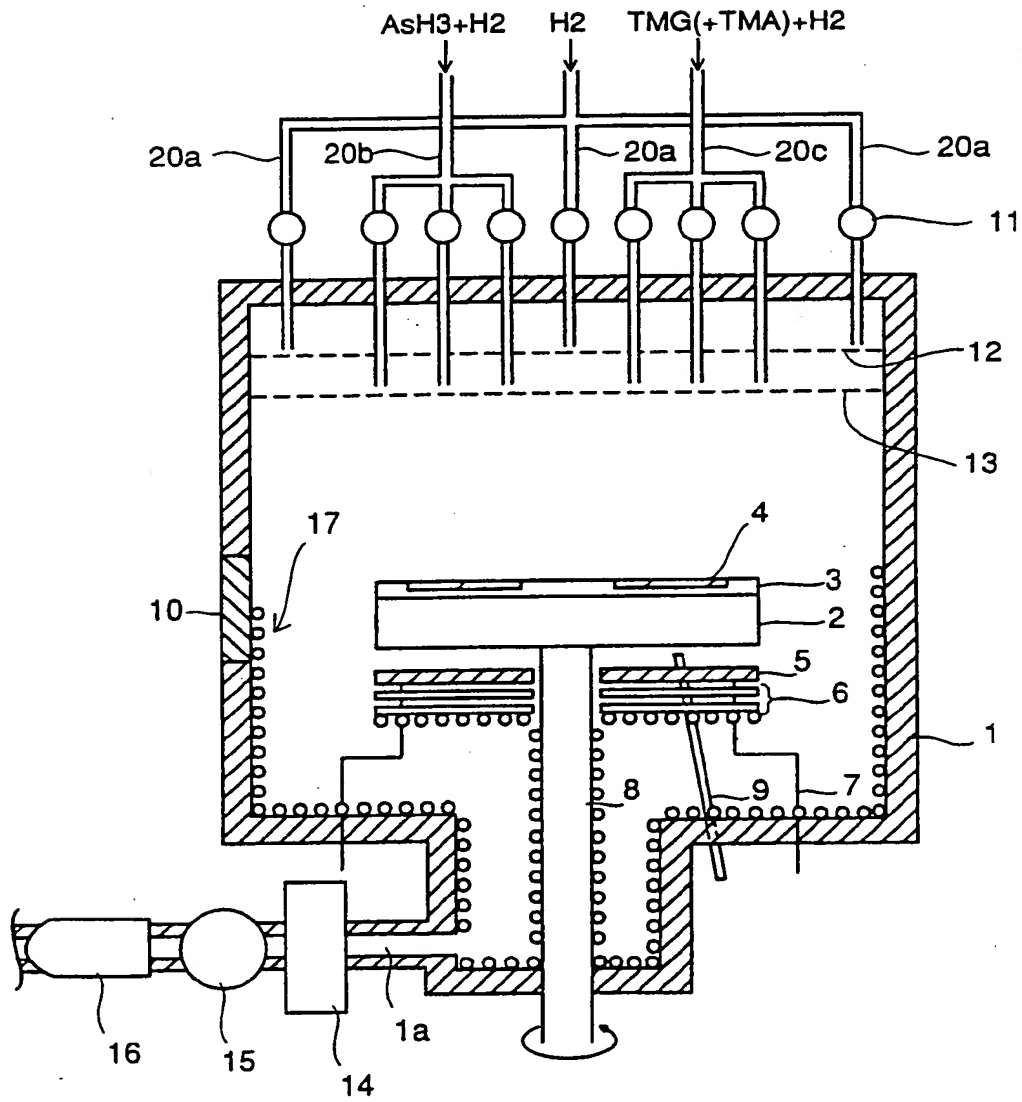
11/13

Fig.11 Prior Art



12/13

Fig.12 Prior Art



13/13  
Prior Art

Fig.13(a)

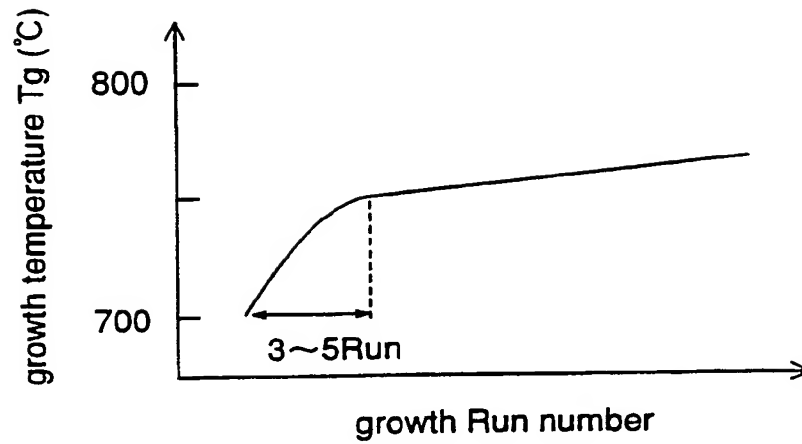


Fig.13(b)

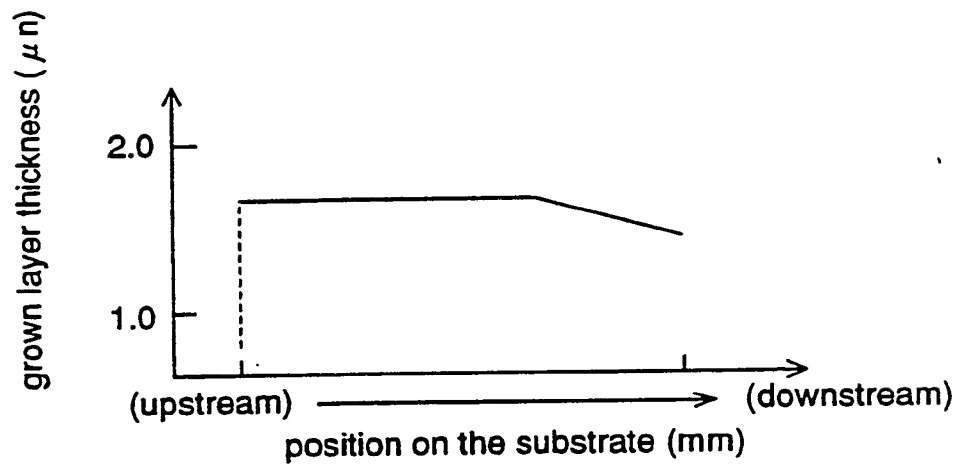
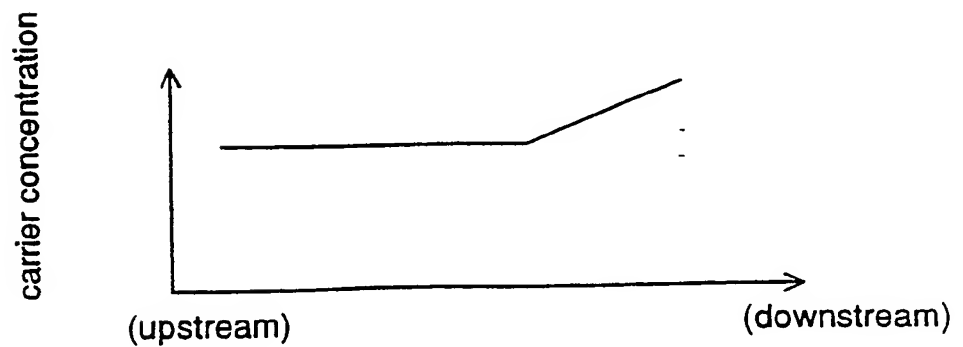


Fig.13(c)



## CHEMICAL VAPOR DEPOSITION APPARATUS

### BACKGROUND OF THE INVENTION

#### Field of the Invention

The present invention relates to a chemical vapor deposition (CVD) apparatus for crystal growth of compound semiconductors or the like using a chemical vapor reaction and, more particularly, to a metal organic chemical vapor deposition (MOCVD) apparatus.

#### Description of the Prior Art

Fig. 11 is a sectional view showing a reaction chamber of a conventional high-speed rotation type MOCVD apparatus. In Fig. 11, a cylindrical reaction chamber 1 is made of SUS. A disc type susceptor 2 is set in the reaction chamber 1. A wafer tray 3 is detachably mounted on the susceptor 2. A semiconductor substrate 4, such as a GaAs substrate, is put in a groove of the wafer tray 3. A circular heater 5 heats the susceptor 2 from a lower portion thereof. A circular heat shielding plate 6 is disposed under the heater 5. An electrode 7 is connected to the heater 5. A rotation axis 8 for rotating the susceptor 2 is fixed to the susceptor 2. A thermocouple 9 detects the temperature of the heater 5. First and second meshes 12 and 13 uniformly spread gases introduced into the reaction chamber 1. An opening 10 is

used when the wafer tray 3 is transported into the reaction chamber 1. A carrier gas supplying pipe 20a and material gas supplying pipes 20b and 20c supply a carrier gas and material gases into the reaction chamber 1, respectively. A needle valve 11 for adjusting the gas flow is attached to each of the pipes 20a, 20b and 20c. A rotary pump 16 is disposed downstream in an exhaust duct 1a of the reaction chamber 1, and a suction pressure of the gas in the reaction chamber 1 is set by a pressure adjusting valve 15 disposed upstream from the rotary pump 16. A filter 14 is disposed upstream from the pressure adjusting valve, which removes dust or the like from the gas in the reaction chamber 1 and send the gas to the pressure adjusting valve 15.

According to the high-speed rotation type CVD apparatus, the susceptor on which the wafers are put is rotated at a high speed while the material gases are supplied, whereby the supplied material gases are collected in whirls to the center of the susceptor. Then, the material gases are uniformly spread from the center of the susceptor toward its circumference. As a result, uniformity of the crystal growth between the wafers can be improved.

Next, the operation during the crystal growth will be described.

The wafer tray 3 on which the semiconductor substrate (GaAs substrate in this case) is disposed at a predetermined



position is transported into the reaction chamber 1 through the opening 10 of the reaction chamber 1. The wafer tray 3 is set on the susceptor 2 in the reaction chamber 1. A hydrogen gas ( $H_2$ ) serving as a carrier gas is introduced from the carrier gas supplying pipe 20a disposed at an upper part of the reaction chamber 1, and the pressure in the reaction chamber 1 is set to a desired pressure, for example, 50 Torr. At this time, the carrier gas ( $H_2$ ) is uniformly spread by the first mesh 12 and supplied into the reaction chamber 1.

Then, the susceptor 2 is gradually rotated to reach a predetermined number of revolutions, for example, 1000 rpm. Then, the heater 5 is heated at a predetermined temperature, for example, 700°C, while arsine ( $AsH_3$ ) of group V material gas is introduced from the material gas supplying pipe 20b into the reaction chamber 1 in order to prevent thermal decomposition (mainly escape of As atoms) of the substrate 4. At this time, heat generated by the heater 5 is reflected by two heat shielding plates 6 disposed under the heater, so that the heat mostly goes toward the susceptor 2. The temperature at this time is monitored by the thermocouple 9 in the reaction chamber 1. In addition, since the decomposition temperature of  $AsH_3$  is higher than that of TMG (to be described later) or the like, a relatively large amount of  $AsH_3$  has to be supplied to

maintain a concentration thereof on the substrate 4.

Then, a material gas for crystal growth, such as TMG, is introduced from the pipe 20c for a desired period of time. Thus,  $\text{AsH}_3$  and TMG (trimethylgallium) are uniformly spread by the second mesh 13 disposed at the upper part of the reaction chamber 1 and reach the GaAs substrate 4. Therefore, uniformity of thickness and carrier concentration of a GaAs film grown on the GaAs substrate 4 is improved.

Then, the supply of the TMG gas is stopped, and the heater 5 is turned off while  $\text{AsH}_3$  is supplied so as to prevent As in the grown GaAs film from escaping. When the temperature falls to a desired point, the supply of the  $\text{AsH}_3$  is stopped and the number of rotations of the susceptor 2 is gradually reduced until the rotation is stopped. Then, the wafer tray 3 is taken out of the reaction chamber 1 through the opening 10, and the GaAs substrate 4 on which the GaAs film is grown is obtained. In addition, in a case of crystal growth of AlGaAs, TMA (trimethylaluminum) is supplied simultaneously with the TMG from the material gas supplying pipe 20c.

Since the conventional CVD apparatus is constituted as described above, exhaustion is performed from the lower part of the reaction chamber, and the reaction gas comes around a region under the susceptor in which the temperature is low. Consequently, as shown in Fig. 12, reaction products 17

generated by thermal decomposition of the reaction gas are attached to the side wall of the reaction chamber 1, the heat shielding plates 6, and the rotation axis 8. As a result, the heat radiation fluctuates, i.e., lowers, because of the attachment of the reaction products 17, whereby the monitored temperature seemingly falls. In order to compensate that, electric power is applied to the heater 5. Consequently, as shown in Fig. 13(a), the actual growth temperature fluctuates during the crystal growth and run-to-run. Especially, the growth temperature largely fluctuates just after maintenance. In addition, cleaning for removing the reaction products 17 from the above-described parts in the reaction chamber 1 has to be periodically carried out.

In addition, since the supply of the material gas is controlled by the needle valve 11, the film thickness, the carrier concentration, or the like becomes uneven at a region on the downstream of gas flow, in the substrate 4 in the reaction chamber. A detailed description will be given referring to Fig. 13. Regarding the film thickness, because a boundary layer becomes thin on the downstream of the wafer, as can be seen from Fig. 13(b), the thickness of the film grown on the wafer is accordingly reduced. Regarding the carrier concentration, since a large amount of group V atoms whose decomposition temperature is high are supplied, the concentration is less uneven in the substrate, but group

III atoms are consumed and its concentration becomes lower toward the downstream. Therefore, the concentration of the group V atoms is seemingly increased on the downstream as shown in Fig. 13(c). As described above, there is unevenness in the film thickness, the carrier concentration, or the like. Consequently, uniformity of product is lowered.

Additionally, the reaction products are attached to the second mesh because of the heat decomposition of the material gases introduced from the pipes disposed at the upper part of the reaction chamber into the reaction chamber, causing the mesh to be stuffed. Consequently, the material gases are not uniformly supplied to the substrate, so that the thickness and the carrier concentration of the film grown on the substrate become uneven. In addition, maintenance for removing the reaction products has to be carried out.

Furthermore, since the decomposition temperature of group V material gas, such as  $\text{AsH}_3$ , is high as described above, the gas is mainly decomposed only on the substrate. As a result, when the material gas and the group III atoms are equivalently supplied, the concentration of the group V atoms (As atoms in case of arsine) supplied for crystal growth on the substrate is lowered. Therefore, a large amount of group V material gas has to be introduced during

the crystal growth, which means that efficiency of the supplied material gases (material efficiency) for the crystal growth is low.

Meanwhile, Japanese Published Patent Application No. 248519/1986 and Japanese Published Patent Application No. 126823/1985 disclose an apparatus comprising two exhaust ducts at a lower part of a reaction chamber, so that reaction gas flow is accelerated under a susceptor to reduce generation of reaction products at the lower part of the reaction chamber. However, in this structure, the reaction gas is not fully prevented from going under the susceptor, and the film thickness, the carrier concentration, and the like are still uneven on the upstream and downstream of the gas flow. In addition, there still exists the above disadvantage that the mesh disposed at an upper part of the reaction chamber is stuffed.

Furthermore, in the conventional example, in order to remove the reaction products deposited in the reaction chamber, the reaction chamber is heated at a prescribed temperature until the reaction products are sufficiently decomposed after the crystal growth while only the carrier gas is supplied or in an evacuated atmosphere. According to this method, however, a maintenance time is extremely increased and manufacturing efficiency is lowered.

Still further, for example, as disclosed in Japanese

Published Patent Application No. 277627/1992 and Japanese Published Patent Application No. 126823/1985, a gas shower electrode ejecting the material gases is heated or the material gas supplying pipes are directly heated. In this structure, however, the material gases are heated up before introduced into the reaction chamber, so that the material gas flow in the gas shower electrode or the material gas supplying pipes is not sufficiently heated up. In addition, since the material gases are decomposed in the gas shower electrode or the material gas supplying pipes, the reaction products are generated and attached therein.

#### SUMMARY OF THE INVENTION

It is an object of the present invention to provide a CVD apparatus in which fluctuation of a growth temperature is reduced and a cleaning cycle of parts in a reaction chamber is increased.

It is another object of the present invention to provide a CVD apparatus capable of carrying out a highly uniformed crystal growth.

It is a further object of the present invention to provide a CVD apparatus in which a mesh disposed under pipes for introducing material gases into a reaction chamber is easily and quickly cleaned, and the material gases are always uniformly supplied onto a substrate.

It is still another object of the present invention to provide a CVD apparatus capable of improving material efficiency by accelerating decomposition of a material gas whose decomposition temperature is high.

Other objects and advantages of the invention will become apparent from the detailed description that follows. The detailed description and specific embodiments described are provided only for illustration since various additions and modifications within the scope of the invention will be apparent to those of skill in the art from the detailed description.

According to a CVD apparatus of the present invention, an exhaust vent is formed at a lower part of a reaction chamber and a detachable cylindrical member is disposed so as to surround parts under a heater. Thus, since parts disposed under a susceptor are surrounded by the cylindrical member, material gases are not likely to go around the parts.

According to a CVD apparatus of the present invention, since an exhaust vent is formed in a side wall of a reaction chamber in the vicinity of a susceptor while material gases are supplied from the upper part of the reaction chamber, the supplied material gases are exhausted near the susceptor and they are not likely to go under the susceptor.

In addition, since a carrier gas introducing pipe for

preventing attachment of products is provided so as to supply a carrier gas from a bottom of the reaction chamber toward a back surface of the susceptor, the material gases are prevented from flowing around a region under the susceptor.

According to a CVD apparatus of the present invention, material gases are supplied from an upper part of a reaction chamber and the material gas is also supplied from an auxiliary pipe toward a part on the downstream of the above material gas flow, in a wafer disposed on a susceptor. Consequently, unevenness of boundary layers on the wafer surface is reduced.

According to a CVD apparatus of the present invention, a heatable mesh is disposed between outlets of pipes for introducing material gases into a reaction chamber and a wafer tray or a susceptor on which a substrate is set, and the mesh is heated at the time of maintenance. As a result, the products attached to the mesh can be quickly removed.

According to a CVD apparatus of the present invention, material gases having different decomposition temperatures are individually supplied from different pipes; outlets of a material gas supplying pipe which supplies the material gas having the higher decomposition temperature is disposed closer to a substrate than outlets of a material gas supplying pipe which supplies the material gas having the



lower decomposition temperature; a heatable mesh is disposed under the outlets of the above pipes; and the material gas having the higher decomposition temperature is decomposed and supplied to the substrate during crystal growth. Thus, a concentration of atoms of the material gas having the higher decomposition temperature on the wafer is increased and efficiency of the material gas is improved. Furthermore, two gases having different decomposition temperatures do not react before reach the wafer.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional view showing an MOCVD apparatus according to a first embodiment of the present invention.

Fig. 2 is a sectional view showing an MOCVD apparatus according to a second embodiment of the present invention.

Fig. 3 is a sectional view showing an MOCVD apparatus according to a third embodiment of the present invention.

Fig. 4 is a sectional view showing an MOCVD apparatus according to a fourth embodiment of the present invention.

Fig. 5 is a sectional view showing an MOCVD apparatus according to a fifth embodiment of the present invention.

Fig. 6 is a sectional view showing an MOCVD apparatus according to a sixth embodiment of the present invention.

Fig. 7 is a plan view showing a structure of a second mesh of the MOCVD apparatus.

Fig. 8 is a sectional view showing an MOCVD apparatus according to a seventh embodiment of the present invention.

Fig. 9 is a perspective view showing a structure of a porous ceramic heater used in the MOCVD apparatus according to an eighth embodiment of the present invention.

Fig. 10 is a sectional view showing an MOCVD apparatus according to ninth and tenth embodiments of the present invention.

Fig. 11 is a sectional view showing a high-speed rotation type of MOCVD apparatus according to the prior art.

Fig. 12 is a sectional view for explaining problems of the prior art MOCVD apparatus.

Figs. 13(a)-13(c) are graphs for explaining problems of the prior art MOCVD apparatus.

#### DESCRIPTION OF PREFERRED EMBODIMENT

##### Embodiment 1

Fig. 1 is a sectional view illustrating an MOCVD apparatus according to a first embodiment of the present invention. In Fig. 1, the same reference numerals as in Figs. 11 and 12 designate the same or corresponding parts. In addition, there are provided a plurality of exhaust vents 1b at a bottom of the reaction chamber 1 and a pipe 1c for introducing a hydrogen gas to a lower part of

the rotation axis 8. Additionally, a detachable cylindrical member 17 (made of quartz, for example) is attached to the bottom of the reaction chamber 1 so as to surround parts under the heater 5.

The operation of the apparatus during crystal growth will be described. Since the process of the crystal growth is the same as described in the conventional example, only an operation which is characteristic of this embodiment will be described.

As shown in Fig. 1, the gas flow during the crystal growth does not go around the parts under the heater 5 because the heat shielding plate 12 surrounds the periphery of the heater 5, the rotation axis 8, and other elements disposed under the susceptor 2. In addition, since a hydrogen ( $H_2$ ) gas as a carrier gas is supplied from the pipe 1c disposed at the bottom of the reaction chamber 1, the material gases are further prevented from going around the parts, whereby the reaction products are not likely to attach onto the parts under the heater 5. Therefore, fluctuation of heat radiation caused by the attachment of the reaction products is reduced, and fluctuation of growth temperature during crystal growth and run-to-run is also reduced. Although the pipe 1c is provided so as to supply the gas from the bottom of the reaction chamber 1 to the rotation axis 8 in the vertical direction in Fig. 1, since

the rotation axis 8 rotates at a high speed during the crystal growth, the supplied carrier gas flows toward the bottom surface of the susceptor 2 along the rotation axis 8 while rotating.

Furthermore, since the outside of the cylindrical member 17 is contaminated mainly, only the member 17 is taken out of the reaction chamber 1 after crystal growth to be cleaned at the time of maintenance, which is very simple.

Still further, since the carrier gas introduced from the pipe 1c is approximately one sixth as much as the material gases and the carrier gas supplied from the upper part of the reaction chamber 1, the material gas flow supplied onto the substrate 4 during crystal growth is not badly influenced.

#### Embodiment 2

Fig. 2 is a sectional view illustrating an MOCVD apparatus according to a second embodiment of the present invention. In Fig. 2, a plurality of exhaust vents 1d are provided at the side wall of the reaction chamber 1 in the vicinity of the susceptor 2 along the periphery of the reaction chamber 1. At least one pair of exhaust vents 1d are oppositely disposed at the side wall of the reaction chamber 1, or a plurality of exhaust vents 1d are preferably radially disposed from the center of the wafer tray 3,

whereby the material gas flow can be uniformly supplied onto the wafer tray 3. In addition, similar to the above-described first embodiment, the pipe 1c is disposed so as to introduce the hydrogen gas from the lower side of the rotation axis 8 in this second embodiment of the present invention. Additionally, although an opening 10 through which the wafer tray 3 is taken in and out is also provided in this second embodiment, it is not shown in the sectional view of Fig. 2.

Next, the operation of the above-described apparatus at the time of crystal growth will be described. Since the process of the crystal growth is the same as in the conventional example, an operation which is characteristic of the second embodiment of the present invention will be only described.

The material gases mostly flow from the center of the wafer tray 3 toward the periphery and, thereafter, flows into the plurality of exhaust vents disposed at the side wall of the reaction chamber 1 as shown in Fig. 2 while the carrier gas is introduced from the pipe 1c disposed under the susceptor 2. Therefore, the material gases are further prevented from going under the susceptor 2. As a result, the reaction products are not likely to attach onto the parts under the heater 5. Consequently, fluctuation of heat radiation caused by the attachment of the products is

reduced and fluctuation of growth temperature during the crystal growth and run-to-run is also reduced. Furthermore, in this case, since the reaction products are hardly attached onto the parts within the reaction chamber 1, maintenance such as cleaning of the parts and the inside of the reaction chamber is not necessary, or its cycle can be significantly increased.

#### Embodiment 3

Fig. 3 is a sectional view illustrating an MOCVD apparatus according to a third embodiment of the invention. In Fig. 3, an exhaust space 24 is formed around the inner peripheral surface of the reaction chamber 1 downward from the susceptor.

Next, the operation of the apparatus during crystal growth will be described. Since process of the crystal growth is the same as described in the conventional example, only an operation which is characteristic of this embodiment will be described.

Gases supplied from the carrier gas supplying pipe 20a and the material gas supplying pipes 20b and 20c flow from the center of the wafer tray 3 toward its periphery and, thereafter, uniformly flow from the periphery of the wafer tray 3 into the exhaust space 24. Then, the gases are exhausted from the reaction chamber 1. At this time, since

the carrier gas is introduced from the pipe 1c disposed under the susceptor 2, the material gases are further prevented from going under the susceptor 2. As a result, the reaction products are not likely to attach to parts disposed under the heater 5. Therefore, similar to the second embodiment of the present invention, fluctuation of heat radiation caused by attachment of the reaction products is reduced and fluctuation of growth temperature during the crystal growth and run-to-run is reduced. Furthermore, maintenance such as cleaning of the parts and the inside of the reaction chamber becomes unnecessary or its cycle is significantly increased. Still further, since the gas is uniformly exhausted from the periphery of the wafer tray 3, evenness of boundary layers in the substrate 4 is improved. Consequently, uniform crystals can be obtained.

#### Embodiment 4

Fig. 4 is a sectional view illustrating an MOCVD apparatus according to a fourth embodiment of the present invention. In Fig. 4, an auxiliary material gas pipe 19 for introducing the material gas from its one end toward the exterior side of the substrate (the side wall side of the reaction chamber) is disposed above the wafer tray 3 in the vicinity thereof. Although there is only one pipe 19 shown in Fig. 4, there are actually a plurality of pipes 19 in the

reaction chamber 1. In addition, the other end of the pipe 19 is connected to a bubbling apparatus 21. To the bubbling apparatus 21 supplied is the carrier gas ( $H_2$  in this case) whose flow rate is controlled by a mass flow controller 22. Thus, a predetermined amount of material gases are generated. The structure other than the above is the same as in the conventional example.

Next, the operation of the apparatus during the crystal growth will be described. According to this embodiment of the present invention, since the material gases are supplied from the upper part of the reaction chamber 1 through each of the pipes 20b and 20c and also through the auxiliary pipe 19, the material gas is supplied also to the exterior side of the wafer (on the downstream) on which the unevenness of the boundary layers is likely to generate. Consequently, uniformity of the grown layer can be easily improved. For example, when the GaAs grown layer is formed, its uniformity is improved by supplying an appropriate amount of TMG through the auxiliary pipe 19.

#### Embodiment 5

Fig. 5 is a sectional view illustrating an MOCVD apparatus according to a fifth embodiment of the present invention. While in the above-described fourth embodiment the material gas is generated by the bubbling apparatus 21



and supplied to the auxiliary pipe 19, in this fifth embodiment the material gases are supplied from the pipes for supplying the necessary material gases and also from the auxiliary pipe 19 connected to the material gas supplying pipe using a bypass pipe 23 as shown in Fig. 5. In this case, the bypass pipe 23 is connected to the material gas supplying pipe 20c, and the needle valve 11 is disposed in the middle thereof. The other parts are the same as in the embodiment 3 of the present invention.

According to the above-described structure, desired material gases can be supplied only by changing piping without additionally providing a mechanism for generating the material gases as in the fourth embodiment, which structure is very simple.

#### Embodiment 6

Fig. 6 is a sectional view illustrating an MOCVD apparatus according to a sixth embodiment of the present invention. In Fig. 6, a mesh heating electrode 25 is connected to the second mesh 26. By applying a voltage to the electrode 25, the second mesh 26 is heated up. Fig. 7 is a view showing a detailed structure of the second mesh 26. As shown in Fig. 7, the second mesh 26 is formed by a resistance wire 26a comprising tungsten or the like and an insulating film 26b comprising quartz or the like. The

electrode 25 is connected to both ends of the resistance wire 26a. Thus, the second mesh 26 is heated by applying a voltage to the electrode 25.

Next, the operation of the apparatus during crystal growth will be described. Although the process for the crystal growth is the same as in the conventional example, since the second mesh 26 is disposed between the wafer tray 3 on which the GaAs substrate 4 is set and the pipes 20b and 20c for introducing the material gases into the reaction chamber 1 can be heated up, it can be easily cleaned by performing the following operation after the crystal growth.

That is, initially, the GaAs substrate 4 is put on the wafer tray 3 or nothing is put thereon. Then, the wafer tray 3 is set on the susceptor 2 in the reaction chamber 1.

Thereafter, the hydrogen gas ( $H_2$ ) serving as the carrier gas is introduced from the pipe 20a disposed at the upper part of the reaction chamber 1 into the reaction chamber 1, and a pressure in the reaction chamber 1 is set at a desired pressure, for example 50 Torr. Alternatively, the reaction chamber 1 is evacuated without introducing the carrier gas into the reaction chamber 1.

Then, a predetermined voltage is applied to the electrode 25 connected to the second mesh 26, whereby the second mesh 26 is heated at a temperature, for example, 300°C or more, in which reaction products are decomposed.

Thus, the second mesh 26 is cleaned for a desired period of time. As a result, the reaction products attached to the second mesh 26 are decomposed by heat and removed from the second mesh 26, and the decomposed reaction products are discharged from the exhaust vent 1a to the outside of the reaction chamber 1. At this time, although a part of the decomposed reaction products could be scattered and attached onto the susceptor, if the wafer tray 3 is put on the susceptor 2 as described above, the reaction products are prevented from attaching onto the susceptor 2. As a result, when crystal growth is carried out again after the cleaning, the heat of the susceptor 2 can be efficiently transferred to the wafer tray 3.

After the second mesh 26 is cooled down, the wafer tray 3 is taken out of the reaction chamber 1 to be prepared for the next crystal growth.

As described above, according to this sixth embodiment of the present invention, since the heatable second mesh for spreading the ejected material gases is disposed under the material gas supplying pipes 20b and 20c, only the second mesh 26 is quickly and selectively heated up at the time of maintenance and the cleaning in the reaction chamber can be quickly performed. In addition, uniformity of thickness and carrier concentration of the film grown on the substrate 4 is improved.

#### Embodiment 7

Fig. 8 is a sectional view illustrating an MOCVD apparatus according to a seventh embodiment of the present invention. Although the second mesh 13 is heated up while the carrier gas flows in the reaction chamber 1 or in an evacuated atmosphere at the time of cleaning in the above-described sixth embodiment, the second mesh 26 is heated up while the hydrogen ( $H_2$ ) gas serving as the carrier gas is introduced together with an etching gas such as  $HCl$  in this seventh embodiment of the present invention as shown in Fig. 8. The structure is the same as in the sixth embodiment.

In this seventh embodiment, since the second mesh 26 is cleaned while the etching gas is supplied, the mesh 26 can be further effectively cleaned as compared with the sixth embodiment of the present invention.

Although  $HCl$  is used as the etching gas in this embodiment, attachment of crystals other than  $GaAs$  and  $InP$  can be well removed by changing the etching gas according to the attached products.

#### Embodiment 8

Fig. 9 is a perspective view illustrating a porous ceramic heater employed in an MOCVD apparatus according to an eighth embodiment of the present invention. While in the

above-described sixth embodiment the second mesh 26 is formed by netting the resistance wire 26a of tungsten and the insulating film 26b of quartz and the mesh heating electrode 25 is connected to both ends of the resistance wire 26a, the electrode 25 may be connected to a porous ceramic heater 30 shown in Fig. 9. In short, another structure may be employed if the temperature can be raised, corrosion resistance is excellent, and the material gases can be transmitted.

#### Embodiment 9

Fig. 10 is a sectional view illustrating an MOCVD apparatus according to a ninth embodiment of the present invention. In Fig. 10, a third mesh 27 having the same structure as the second mesh 24 is disposed under the second mesh 24, and the mesh heating electrode 25 is connected thereto. Outlets of a material gas supplying pipe 20d are positioned between the second mesh 24 and the third mesh 27.

The operation of this MOCVD apparatus will be described. First, the GaAs substrate 4 is put in a groove of the wafer tray 3 and the wafer tray 3 is set on the susceptor 2 in the reaction chamber 1. Then, a hydrogen ( $H_2$ ) gas serving as the carrier gas is supplied from the pipe 20a disposed at the upper part of the reaction chamber 1 into the reaction chamber 1, and pressure in the reaction

chamber 1 is set to a desired pressure, for example, 50 Torr.

Then, the susceptor 2 is rotated and the heater 5 is heated up while arsine ( $\text{AsH}_3$ ) of group V material gas is introduced from the material gas supplying pipe 20b into the reaction chamber 1 in order to prevent heat decomposition of the GaAs substrate 4. Thus, the GaAs substrate 4 is heated at a desired temperature, for example,  $700^\circ\text{C}$ , by raising the temperature of the susceptor 2. At the same time, a voltage is applied to the electrode 25 connected to the second mesh 24 disposed under the pipe 20b to heat the second mesh 24 at approximately 100 to  $300^\circ\text{C}$ . Thus,  $\text{AsH}_3$  which passed through the second mesh 24 is previously heated and decomposition on the GaAs substrate 4 is accelerated, whereby the concentration of As on the GaAs substrate 4 is increased and the rate of effectively used material is increased.

Then, a material gas of group III such as TMG, is introduced from the material gas supplying pipe 20d for crystal growth. The  $\text{AsH}_3$  gas and the TMG gas are uniformly spread by the second mesh 24 disposed under the pipe 20b for supplying the  $\text{AsH}_3$  gas and the third mesh 27 disposed under the pipe 20d for supplying the TMG gas, respectively, to reach the GaAs substrate 4. Thus, uniformity of thickness composition, and carrier concentration of the GaAs film grown on the GaAs substrate 4 is improved. In addition,

since the TMG gas is supplied from the pipe 20d whose outlets are positioned under the second mesh 24, it is prevented that the TMG gas is decomposed before reaches the GaAs substrate 4 and attaches to the third mesh 27 by a reaction with the  $\text{AsH}_3$ .

Then, the supply of the TMG gas is stopped and the GaAs substrate 4 is cooled down by suppressing the heating of the heater 5 while supplying the  $\text{AsH}_3$  gas. Then, the heating of the second mesh and the supply of the  $\text{AsH}_3$  gas are stopped and then, the rotation of the susceptor 2 is stopped. Then, the wafer tray 3 is taken out of the reaction chamber 1 and the GaAs substrate 4 on which crystals have been grown is taken out.

In addition, in a case where the mesh 26 is stuffed with the reaction products after the predetermined number of growth, similar to the sixth embodiment of the present invention, a voltage is applied to the mesh heating electrode 25 connected to the third mesh 27 to clean the mesh. In addition, if necessary, the mesh heating electrode 25 connected to the second mesh 24 may be heated up by an application of a voltage.

Thus, according to this ninth embodiment of the present invention, the heatable second mesh 24 is disposed under the pipe 20b for supplying the  $\text{AsH}_3$  gas in the vicinity thereof, the outlets of the pipe 20d for supplying the TMG gas are

positioned under the second mesh 24, and the third mesh 27 is disposed under the outlets of the pipe 20d. In addition, during the crystal growth, the second mesh 24 is heated up, and  $\text{AsH}_3$  having a decomposition temperature higher than that of TMG and a decomposition efficiency lower than that of TMG is previously heated to be supplied to the substrate 4. Consequently, the decomposition of  $\text{AsH}_3$  on the substrate 4 is accelerated. As a result, the concentration of group V gas on the substrate 4 can be increased and the rate of efficiently used material gases for the crystal growth is increased.

Furthermore, the outlets of the material gas supplying pipe 20d for supplying the TMG whose decomposition temperature is lower than that of  $\text{AsH}_3$  are positioned under the second mesh 24, and the third mesh 27 is disposed under the outlets of the pipe 20d, so that it will not occur that the TMG gas is decomposed and the  $\text{GaH}_3$  gas previously heated by the second mesh 24 reacts and attaches onto the third mesh 27.

#### Embodiment 10

An MOCVD apparatus according to a tenth embodiment of the present invention will be described. Although the second mesh 24 is heated up at 100 to 300°C during the crystal growth to previously heat  $\text{AsH}_3$  whose decomposition



temperature is high in the ninth embodiment of the present invention, the second mesh 24 may be heated at a high temperature of 700°C or more to decompose  $\text{AsH}_3$  there. In this case, even if  $\text{AsH}_3$  is decomposed, since the temperature of the second mesh 24 is sufficiently higher than the decomposition temperature of  $\text{AsH}_3$ , the reaction products are not likely to attach to the second mesh 24. Thus, use-efficiency of  $\text{AsH}_3$  is further improved.

Furthermore, by also heating up the third mesh 27 at a temperature much higher than the decomposition temperature of the material gas, such as  $\text{AsH}_3$  or TMG, the use-efficiency of the material gas supplied from the pipe 20d for supplying the material gas, such as TMG, is also improved. In this case, however, the material gases decomposed in the vicinity of the third mesh 27 could react with each other and their reaction products are likely to attach to the side wall of the reaction chamber 1.

Furthermore, although GaAs crystals are grown using  $\text{AsH}_3$  as the group V material gas and TMG as the group III material gas according to each of the above embodiments, the same effect as the above-described embodiments can be expected regarding crystal growth of another material such as AlGaAs, InP, InGaAsP, or AlGaInP. In addition, regarding crystal growth other than crystal growth of group III - V materials, the same effect can be expected by using two or

more kinds of material gasses having different decomposition temperatures.

Furthermore, although the exhaust vent 1b is disposed so as to exhaust the material gases from the bottom of the reaction chamber 1 in the vertical direction according to the first embodiment of the present invention, the exhaust vent may be disposed so as to exhaust the material gases at the bottom of the reaction chamber 1 in the horizontal direction.

As described above, according to the CVD apparatus of the present invention, since the parts disposed under the heater are covered with the cylindrical member, the reaction products are not likely to attach to the parts surrounded by the member. Consequently, the growth temperature is stabilized and the maintenance in the reaction chamber is facilitated.

In addition, according to the CVD apparatus of the present invention, since the material gases are exhausted around the susceptor, the material gases are not likely to go under the susceptor. Thus, the reaction products are not likely to attach to the parts under the susceptor, whereby the growth temperature is stabilized and the maintenance in the reaction chamber is facilitated.

Still further, by supplying the carrier gas from the bottom of the reaction chamber toward the back surface of

the susceptor, the material gases are further prevented from going under the susceptor.

In addition, according to the CVD apparatus of the present invention, since the material gas is supplied in an auxiliary manner to the part on the downstream of material gas flow, in the wafer disposed on the susceptor, unevenness of boundary layers in the wafer is improved and there can be formed the grown layer having high uniformity of film thickness, carrier concentration, and the like.

Furthermore, according to the CVD apparatus of the present invention, since the heatable mesh is disposed between the outlets of the pipes for introducing the material gases into the reaction chamber and the wafer tray or the susceptor on which the substrate is set, the mesh can be easily cleaned, and the material gases are always uniformly supplied onto the substrate, whereby uniformity of crystal growth can be improved.

Additionally, according to the CVD apparatus of the present invention, the pipe for introducing the material gas whose decomposition temperature is relatively high is disposed above the pipe for introducing the material gas whose decomposition temperature is relatively low, the heatable mesh is provided under each area, and the material gas whose decomposition temperature is relatively high is previously heated or decomposed and supplied to the wafer.

Consequently, use-efficiency of the material gas of high decomposition temperature can be improved.

WHAT IS CLAIMED IS:

1. A chemical vapor deposition apparatus for crystal growth on a wafer disposed in a reaction chamber in which material gases are supplied from an upper part of the reaction chamber while the material gases are exhausted from a bottom of the reaction chamber , comprising:

a susceptor on which the wafer is put;  
a heater disposed under the susceptor , for heating the susceptor ; and

a detachable cylindrical member disposed at the bottom of the reaction chamber so as to cover parts under the susceptor and prevent the material gases from flowing around the parts under the susceptor .

2. A chemical vapor deposition apparatus for crystal growth on a wafer disposed in a reaction chamber while material gases are supplied from an upper part of the reaction chamber , comprising:

a susceptor on which the wafer is put;  
a heater disposed under the susceptor , for heating the susceptor ; and

an exhaust vent disposed in a side wall of the reaction chamber in the vicinity of the susceptor .

3. A chemical vapor deposition apparatus as defined in claim 2 further comprising a plurality of exhaust pipes connected to said exhaust vent , each pipe having a pressure adjusting mechanism for adjusting an exhaust pressure of the material gas.

4. A chemical vapor deposition apparatus as defined in claim 2 wherein the exhaust vent is formed between an inner side wall of the reaction chamber and a partition wall formed over the whole inner periphery thereof at a predetermined interval, and

the material gases are exhausted outside the reaction chamber through a space between the inner side wall and the partition wall of the reaction chamber .

5. A chemical vapor deposition apparatus as defined in claim 1 further comprising a carrier gas introducing pipe for introducing a carrier gas from the bottom of the reaction chamber toward a back surface of the susceptor to prevent the material gases from flowing to parts under the susceptor .

6. A chemical vapor deposition apparatus as defined in claim 2 further comprising a carrier gas introducing pipe for introducing a carrier gas from the

bottom of the reaction chamber toward a back surface of the susceptor to prevent the material gases from flowing to parts under the susceptor .

7. A chemical vapor deposition apparatus having a susceptor on which a wafer is put, in a reaction chamber in which material gases are supplied from an upper part of the reaction chamber and flow from the center of the susceptor toward its periphery on the susceptor , comprising:

an auxiliary material gas supplying pipe for supplying the material gas in an auxiliary manner to a part on the downstream of the material gas flow, in a wafer put on the susceptor .

8. A chemical vapor deposition apparatus as defined in claim 7 further including:

a plurality of material gas supplying pipes for supplying the material gases according to kinds of the material gases, and

said auxiliary material gas supplying pipe diverging from the material gas supplying pipe for supplying the same kind of material gas as that supplied from the auxiliary pipe . .

9. A chemical vapor deposition apparatus for crystal growth on a wafer disposed in a reaction chamber in which material gases are supplied from an upper part of the reaction chamber, comprising:

material gas supplying pipes for supplying the material gases into the reaction chamber ; a mesh disposed under outlets of the material gas supplying pipes, for uniformly spreading the supplied gas; and

mesh heating means for heating said mesh to remove reaction products attached to the mesh at the time of cleaning of the apparatus.

10. A chemical vapor deposition apparatus as defined in claim 9 wherein an etching gas for decomposing the reaction products is introduced together with the carrier gas from the material gas supplying pipe while the mesh is heated.

11. A chemical vapor deposition apparatus as defined in claim claim 9 wherein said mesh is a porous ceramic heater, and said mesh is heated by applying a voltage to said ceramic heater.

12. A chemical vapor deposition apparatus for



crystal growth on a wafer disposed in a reaction chamber in which material gases are supplied from an upper part of the reaction chamber , comprising:

a first material gas supplying pipe for supplying a first material gas, and having an outlet;

a second material gas supplying pipe for supplying a second material gas having a decomposition temperature lower than that of the first material gas, said second material gas supplying pipe having an outlet disposed closer to the wafer than the outlet of the first material gas supplying pipe ;

a first mesh disposed under the first material gas supplying pipe , for uniformly spreading the first material gas supplied from the pipe;

a second mesh disposed under the second material gas supplying pipe , for uniformly spreading the second material gas supplied from the pipe; and

heating means for heating said first and second meshes ,

wherein the first material gas is previously heated by heating the first mesh during crystal growth.

13. A chemical vapor deposition apparatus for crystal growth on a wafer . disposed in a reaction chamber in which material gases are supplied from an upper part

of the reaction chamber , comprising:

a first material gas supplying pipe for supplying a first material gas, and having an outlet;

a second material gas supplying pipe for supplying a second material gas having a decomposition temperature lower than that of the first material gas, said second material gas supplying pipe having an outlet disposed closer to the wafer than the outlet of the first material gas supplying pipe ;

a first mesh disposed under the first material gas supplying pipe , for uniformly spreading the first material gases supplied from the pipes;

a second mesh disposed under the second material gas supplying pipe - , for uniformly spreading the second material gas supplied from the pipe; and

a heating mechanism . . for heating the first and second meshes ,

wherein the first material gas is decomposed by heating the first mesh at a temperature higher than the decomposition temperature of the first material gas to be supplied onto the wafer during crystal growth.

14. A chemical vapor deposition apparatus as defined in claim 12 wherein reaction products attached to the second mesh are removed by heating the second mesh when

the apparatus is cleaned.

15. A chemical vapor deposition apparatus as defined in claim 13 wherein reaction products attached to the second mesh are removed by heating the second mesh when the apparatus is cleaned.

16. Chemical vapor deposition apparatus substantially as herein described with reference to any of figures 1 to 5, figures 6 and 7, or any of figures 8 to 10 of the accompanying drawings.

**Relevant Technical Fields**

- (i) UK Cl (Ed.N) C7F (FHB, FHE, FHX)  
 (ii) Int Cl (Ed.6) C23C (16/44, 16/46); C30B (31/12, 31/14)

Search Examiner  
 P G BEDDOE

Date of completion of Search  
 11 NOVEMBER 1994

**Databases (see below)**

(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

Documents considered relevant following a search in respect of Claims :-  
 1, 5 AND IN PART 16

(ii) ONLINE DATABASES: WPI, CLAIMS

**Categories of documents**

- X: Document indicating lack of novelty or of inventive step. P: Document published on or after the declared priority date but before the filing date of the present application.  
 Y: Document indicating lack of inventive step if combined with one or more other documents of the same category. E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.  
 A: Document indicating technological background and/or state of the art. &: Member of the same patent family; corresponding document

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 1181101	(SIEMENS) see especially Figure 1; page 3 lines 46 to 80	1
X	EP 0291181 A2	(LELAND STANFORD) see especially lower half of Figure 1 (numeral 14)	1
X	EP 0260718 A2	(FUJITSU) see especially Figure 4 (base of reaction chamber) and column 4 line 38 to column 5 line 20	1
X	EP 0095887 A1	(FUJITSU) see especially Figure 1, page 2 line 23 to page 3 line 9	1
X	US 5177878	(U S PHILIPS) see especially Figure 1 (lower half); column 5 line 9 to column 6 line 15	1
X	US 5063031	(KABUSHIKI) see especially part "31" in Figure 3	1
X	US 5011705	(SAGAMI) see especially Figure 4	1

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).